6.6 The Ionosphere and Communications

If we were limited to line-of-sight communications, long distance wireless communication, like ship-to-shore communication, would be impossible. At the turn of the century, Marconi, the inventor of wireless telegraphy, boldly tried such long distance communication without any evidence either empirical or theoretical that it was possible. When the experiment worked, but only at night, physicists scrambled to determine why (using Maxwell's equations, of course). It was Oliver Heaviside, a mathematical physicist with strong engineering interests, who hypothesized that an invisible electromagnetic "mirror" surrounded the earth.

What he meant was that at optical frequencies (and others as it turned out), the mirror was transparent, but at the frequencies Marconi used, it reflected electromagnetic radiation back to earth. He had predicted the existence of the ionosphere, a plasma that encompasses the earth at altitudes hi between 80 and 180 km that reacts to solar radiation: It becomes transparent at Marconi's frequencies during the day, but becomes a mirror at night when solar radiation diminishes. The maximum distance along the earth's surface that can be reached by a **single** ionospheric refection is

$$2R\arccos\left(\frac{R}{R+h_i}\right)$$

which ranges between 2,010 and 3,000 km when we substitute minimum and maximum ionospheric altitudes. This distance does not span the United States or cross the Atlantic; for transatlantic communication, at least two reflections would be required.

The communication delay encountered with a single refection in this channel is

$$\frac{2\sqrt{2Rh_i+{h_i}^2}}{c},$$

which ranges between 6.8 and 10 ms, again a small time interval.

6.7 Communication with Satellites

Global wireless communication relies on satellites. Here, ground stations transmit to orbiting satellites that amplify the signal and retransmit it back to earth. Satellites will move across the sky unless they are in **geosynchronous orbits**, where the time for one revolution about the equator exactly matches the earth's rotation time of one day. TV satellites would require the homeowner to continually adjust his or her antenna if the satellite weren't in geosynchronous orbit. Newton's equations applied to orbiting bodies predict that the time *T* for one orbit is related to distance from the earth's center *R* as

$$R=\sqrt[3]{\frac{GMT^2}{4\pi^2}}$$